

GEOTHERMAL RESOURCES DEVELOPMENT IN TIBET, CHINA

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ABSTRACT

Tibet is located in the eastern section of the global Mediterranean-Himalaya geothermal zone. High temperature geothermal resources are distributed throughout the region. However, the existing utilization is on a small scale. The Yangbajain geothermal power plant started geothermal electricity production from a 1 MWe testing unit in 1977. Consequent growth increased it to 24.18 MWe of installed capacity. It has produced a total of 26.81 GWh of electricity. Its electric supply is important for the town of Lhasa. Other tests of a 2 MWe plant at Langju and a 1 MWe plant at Nagqu did not last. Along with social economic growth and rising people's livelihood, future energy shortage is indicated.

Developments were not able to satisfy local demand. In order to maintain the natural ecological environment, energy planning in Tibet involves now development of mainly renewable energy resources. Hydropower, for example, will be increased and future geothermal power generation from high temperature fields will provide important support, especially to overcome winter electricity shortage. In 2011, a 400 kWe pilot geothermal plant was commissioned at the Yangyi geothermal field and has been run successfully. New geothermal production wells are being drilled this year. Two power plants (each 16MWe) have been planned for the first and second stage of geothermal power generation at Yangyi.

1. INTRODUCTION

Tibet is located in the eastern section of the Mediterranean-Himalaya geothermal zone. It is rich in high temperature geothermal resources. A total electric power potential of c. 3,040 MWe is indicated for all high and sub-high temperature geothermal systems in the Tibet section of the Yunnan-Tibet Geothermal Zone (Liao and Zhao, 1999). The Tibet Bureau of Geology and Exploration has carried out detailed geothermal surveys and preliminary exploration of ten geothermal fields, mainly along the Qinghai-Tibet railway in the Central Tibet region. Their power potential for generation is c.137 MWe (Zheng and Wang, 2010).

Geothermal resource development and utilization in Tibet are so far only on a small scale and at low level. The Yangbajain Geothermal Power Plant is the first high temperature geothermal power plant in China. It has provided high quality power supply for Tibet during the past 30 some years. It has an installed capacity of 24.18MWe (Bao et al., 2006; Dor et al., 2007) and produces now 140GWh electricity annually. Its capacity utilization factor is 0.68

Tibet lacks conventional energy resources. Geothermal power generation is an ideal supplement to reduce the shortage of power supply. In order to solve the electric shortage problem, Tibet ran a tortuous path. The Yamzho Yumco Hydropower Plant has not fulfilled its expected mission. In recent years geothermal power generation was brought back into the agenda. After some small generation tests, the construction of the Yangyi Geothermal Power Plant has been started (first stage engineering of 16 MWe).

2. GEOTHERMAL RESOURCES & EXPLORATION

Worldwide high temperature geothermal resources are mostly concentrated in global geothermal zones. These are the Pacific Ring of Fire, the Atlantic Mid Ocean Ridge and the Mediterranean-Himalayan Zone. These zones are controlled by major geological (plate) tectonics. The Himalayan geothermal zone is the eastern part of the Mediterranean-Himalayan Geothermal Zone. It crosses Tibet in west-east direction along the Yarlung Zangbo "suture line". The suture line is a geological boundary between Eurasian (crust) Plate and the Indian (crust) Plate. The suture line is a weak link, where stress is easily concentrated during compaction, collision and friction movements. Faults in the suture zone serve as channels for heat up-flow. Almost all high temperature geothermal resources and most medium-low temperature geothermal manifestation are distributed along this wide zone. Its width is about 400 km, and the length is some 2,000 km at the country boundary (Dor, 2008).

Various types of high, medium and low temperature natural geothermal manifestations occur in Tibet. There are a total of 45 locations exhibiting boiling springs, boiling fountains, hydrothermal eruptions and geysers with temperatures above local boiling point. High temperature springs with temperatures ranging from 80°C to boiling point occur in 7 locations. Medium-high temperature springs with temperatures ranging from 60 to 80°C occur in 83 locations. Medium temperature springs with temperatures ranging from 40 to 60°C were found in 109 locations and low temperature springs with temperatures ranging from 25 to 40°C at 62 sites.

Yangbajain is one of the most famous geothermal fields, located in Dangxiong County, about 90 km north-west of Lhasa. Here one finds many boiling springs, hot springs, hot lakes, steaming ground and hydrothermal eruption craters. In the area, the highest discharge temperature is 93°C, higher than the local boiling point temperature. Geothermal exploration has been carried out since the mid 1970s. Two phase fluids of steam and thermal water of 141-172°C were found at about 200 m depth. Geothermal power generation started in 1977 and became an important source of electricity supplying Lhasa.

The Dagjia geyser, located in Angren County, is the biggest geyser in China. It occurs at 5,080 m above sea level, the

highest geyser of its kind in the world. There is an irregular interval between eruptions reaching up to 20 m in height. The vent occurs on a large terrace of siliceous sinter and more than 200 thermal manifestations are scattered around its location. Amongst these are close to a 100 boiling springs with temperatures of 86°C and there are other hot springs, warm springs and hot ponds, etc. The total flow rate is about 7,000 m³/d.

The Gulug boiling fountain is located in Nagqu County near the Qinghai-Tibet railway. In association, there are various manifestations such as boiling fountains, boiling springs, warm springs, fumaroles and siliceous sinter, most of them at temperatures of 85-86°C. The maximum temperature of 92°C is higher than the local boiling point. The total flow rate is 500-700 m³/d and the amount of total dissolved solids (TDS) is nearly 4 g/l.

According to the study of Zhijie Liao et al.(1999) in their monograph "Yunnan-Tibet Geothermal Zone", there are 57 high temperature geothermal systems located in the Himalayan Geothermal Zone. The total anomalous energy is c. 85 (10¹⁸) J. The geothermal power generation potential is c.1,930 MWe. In addition, intermediate temperature geothermal systems have a potential of c. 1,110 MWe. Hence, the Himalayan Geothermal Zone has a total potential of the order of 3,040 MWe for geothermal power generation (Liao and Zhao, 1999).

The Tibet Bureau of Geology and Exploration has carried out some detailed geothermal surveys and preliminary explorations in ten geothermal fields, mainly along the Qinghai-Tibet railway in the Central Tibet region. Geothermal resource assessment of these fields is listed in Table 1. The Yangbajain Geothermal Field was explored for its shallow (c. 200m) and deep reservoir (1,000-3,000 m). The National Reserves Committee of Geology and Mineral Resources has approved a power generation of 34 MWe and 31.8 MWe respectively (Zheng and Wang, 2010).

Table 1: Resource Potential for Power Generation in Geothermal Fields in Tibet

Geothermal field	Reservoir temp. (°C)	Power generation potential (MWe)
Yangbajain shallow (24.18MW plant)	160	34.0
Yangbajain deep (2MW pilot)	250	31.8
Yangyi (400kW pilot)	200	30.0
Nagqu (1MW old plant)	115	5.78
Latogka	95	0.96
Langju (2MW old plant)	103	1.01
Gulug	154	8.41
Dongweng	120	7.11
Xumai	110	6.45
Jidaguo	135	5.59
Qucain	138	2.81
Gariqiao	130	2.73
Tuoma	108	0.55
Luoma	108	0.29
Total		137.5

* After Tibet Geothermal Geological Team (partially revised)

Except for the developed Yangbajain Geothermal Field, the Yangyi Geothermal Field has the best potential for present development. The Yangyi field is located 55 km south of the Yangbajain field. It is 72 km away from Lhasa, its elevation is 4,550m above sea level. Detailed geothermal surveys and explorations have been carried out at Yangyi field by the Tibet Bureau of Geology and Exploration during 1985-1990. The National Reserves Committee of Geology and Mineral Resources has approved a power generation of 30 MWe.

The geothermal reconnaissance and detailed surveys of the Yangyi geothermal field involved drilling of 32 drill holes with a total length of 8,377 m. Lip pressure tests were carried out in 3 wells. Subsequent exploration completed 15 drill holes with a total length of 11,813 m. Yield tests were carried out for groups of wells. The geothermal field covers an area of 10 km². The reservoir has a maximum temperature of 207 °C. The shut well pressure is 2.8-9.4 kgf/cm². Working pressures are 0.95-11.3 kgf/cm² and working temperatures 105~190°C. The maximum well head temperature is 201 °C. Single wells yield 772-8,970 t/d of total flow of steam and water, with 82.8-2,410 t/d of steam. The exploration depth is about 1,000 m. Its estimated potential may be 50 MWe if deep resources are added (Zheng and Pan, 2009). The Yangyi geothermal field appears to be a better prospect than the Yangbajain geothermal field due to higher temperature, higher pressure,



and higher yield of fluids.

Fig. 1 Distribution Map of Hot Springs in Tibet

3. YANGBAJAIN GEOTHERMAL POWER PLANT

The Yangbajain Geothermal Power Plant is the first high temperature geothermal power plant in China. Its first 1MWe pilot plant unit was tested with success in 1977. Along with further drilling of production wells in the geothermal field, the Southwest Electric Power Design Institute completed the design of the plant. The Qingdao Jieneng Steam Turbine Factory completed a new design and the construction of the 3MWe unit.

The Yangbajain Geothermal Power Plant consists of two plants: the south plant and the north plant. There are a 1 MW test unit and 3 × 3MWe units installed in the southern plant, it was completed in 1985. In the northern plant there are a 3.18 MWe Japanese unit and 4 × 3 MWe units completed in 1991. The total installed capacity for both plants was 25.18 MWe. The 1 MWe test unit was retired in 1985. The geothermal electricity from Yangbajain supplies Lhasa.

The Yangbajain Geothermal Power Plant represents the present level for Chinese geothermal power generation. During the period of construction and installation for 14

years, The Qingdao Jieneng Steam Turbine Factory heard comments from the user and improved its products continuously. The Yangbajain Geothermal Power Plant improved its own management and operation progressively too. The annual generation was 86.6 GWh in 1991. However, it is about 140 GWh in recent years. The total electricity generation from the plant reached 2,681 GWh at the end of 2011.

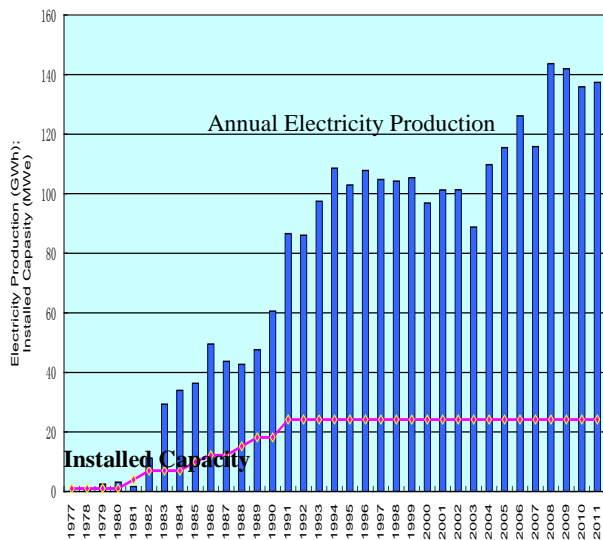


Fig.2 Yangbajain Geothermal power generation

The Yangbajain Geothermal Power Plant mainly exploits a shallow geothermal reservoir. High temperature geothermal fluids came from granitic basement and recharge a Quaternary sand and gravel reservoir. It is covered by clayey soil and travertine deposits forming a cap rock. The wellhead temperature was 141-174°C for the shallow 200 m deep production wells. After exploitation for 30 some years, the temperatures decreased to 120-130°C. For a pilot type exploitation of the deep reservoir 2×1MWe screw expander units use the geothermal fluids from one deep well (ZK4001).

4. GEOTHERMAL DIRECT USE

Only little geothermal energy is used for direct use in Tibet. However, geothermal water is used for greenhouses, bathing, medical care and tourism, space heating, industrial washing and drinking mineral water bottling.

4.1 Geothermal Greenhouse

Yangbajain geothermal power plant discharges about 50,000 m³ of hot water (80°C) per day. Most of this water is discharges into the Zangbu River, although a small part is used for greenhouses. A typical greenhouse at elevation of 4,300 m a.s.l. is of half spherical shape, covering 1,000 m², and carries a steel framework with a glass top. Other small simple greenhouses cover a total area of 26,000 m². Over 70 types of vegetables are grown, with an annual production capacity of about 300,000 kg. There are similar greenhouses in Nagqu and at Langju in the Arli district.

4.2 Hot Spring Bathing

Tibetan people take baths in hot springs if the spring is close by their village. Hot spring baths are usually simple.

Some of bath pools are situated in houses, some are in open air. They are free of charge in rural areas.

4.3 Medical Care and Tourism

The Rutog Hot Spring Mountain Villa was created several years ago. The Rutog hot spring is located in Mozhugongka County, close to Lhasa city. It was developed for spa usage, medical care and tourism. In addition, there is a geothermal swimming pool in the Yangbajain area using waste (separated) water from the geothermal power plant. Similar utilization occurs also in Kangbu in Yadong County, Quzika in Mangkang County and Ningzhong in Dangxiong County.

4.4 Geothermal Space Heating

It was considered several times to use waste thermal water from Yangbajain Geothermal Power Plant for district space heating in Lhasa. The feasibility study and calculation showed that it would satisfy 1,373,000 m² of space heating, which is equivalent to 35.1% of the whole area of houses and public buildings in Lhasa city. If one uses also heat pumps to extract waste heat from tail water, this project could satisfy 2,460,000 m² of space heating, which is equivalent to 62.9% of total demand. Normal geothermal space heating has been implemented in Nagqu County. There was a 30,000 m² of area for geothermal direct space heating at the beginning. Due to scaling problem it decreased later. Heat exchangers were then used to avoid scaling problem. The Nagqu County government building uses now geothermal indirect heating for 10,000 m².

4.5 Hot Water Industrial Washing

There is some small scale utilization for washing of sheep's wool and extracting tinkalite (a mineral product).

4.6 Bottling Drinking Mineral Water

The hot spring water in Longma in Jiangzi County and at Xiamula in Anduo County have the standard of natural mineral drinking water. These waters are now bottled for consumption.

5. CIRCUITOUS EXPLORING FOR SOLVING TIBETS SHORTAGE OF POWER SUPPLY

Tibet lacks conventional coal, oil and natural gas energy resources. Tibet is located in a remote region and is backward in economy. There is a serious shortage of power supply in Tibet. About 42% of the population was without electric supply in 2005. It was still 30% in 2009. In the past decades Tibet has been trying to solve situations of electric shortage but Tibet ran a tortuous path.

The Langju hot spring is located in Siquanhe Town, in the Arli region. Its temperature is 78°C with a total flow rate 400-600 m³/d. A small geothermal power plant of 2×1 MWe units was constructed in 1983 without prior geothermal exploration. Geothermal wells were drilled to a depth of about 100 m. The wellhead temperature was 103°C producing a two-phase flow at local elevation of 4,800m a.s.l. The construction was completed in 1985. However, the geothermal wells did not produce sufficient fluids. One unit was kept to produce intermittently 400 kWe electricity but was stopped later.

The Nagqu warm springs are located in Nagqu Town of Nagqu County. The discharging thermal water had a temperature of 40-61°C. A small scale binary geothermal power plant was constructed in 1993. Geothermal wells produced fluids with 115°C temperature. It used an Ormat binary unit of 1MWe, aided by a United Nations project, and started producing electricity in 1994. But due to serious (calcite) scaling problems it was stopped in 1999.

In order to reduce such situation of power supply shortage, Tibet started to develop the Yamzho Yumco Hydropower Plant at the beginning of the 1990s. A tunnel was designed and excavated to discharge Yamzho Yumco Lake water into the Yarlung Zangbo River for a 700 m fall. It was planned to install a 112.5 MWe hydropower plant. However, geothermal workers proposed to develop the Yangyi Geothermal Power Plant instead. The argument was used that the Yamzho Yumco Lake had only limited recharge from snow melting annually and that it was wrong to discharge the salty water of the lake into a fresh water river. But the faction supporting the hydropower scheme suggested that river water could be pumped back into the lake during idle hours. The Yamzho Yumco Hydropower Plant started running in 1997. But it ran only about 2,000 hours per year. Its capacity factor was only half that of other similar plants. In 2011 the water level of the Yamzho Yumco Lake had decreased to the bottom level of the water conveying tunnel. Thus it finished its expected mission. During the 15 years lifetime it produced 2,700 GWh of electricity. There was no river water pumped back to the lake during the period.

6. NEW PROSPECTS FOR GEOTHERMAL POWER GENERATION

Tibet is the largest natural ecological landscape worldwide. Its 1.22 million km² of land retains its original ecology. It is for the lack of conventional coal, oil and natural gas energy resources in Tibet that high temperature geothermal power will be used to provide important support, especially for the winter electric shortage. Hydropower can be developed under certain conditions in Tibet. However, there is a general lack of natural water supply especially during the winter season. Being faced with day by day increase of electricity demand in Tibet (Shi Dinghuan et al., 2007), small scale hydropower schemes can solve the lack of electricity in remote areas. Geothermal power generation, however, is able to remit the shortage of power supply in the Tibet grid, especially during winter.

Considering the failure and frustration of the Yamzho Yumco Hydropower Plant scheme, one can argue that if one had constructed the Yangyi Geothermal Power Plant earlier, its 30MW of installed capacity would also have produced 2,700 GWh of electricity when running 6,000 hours per year (as at Yangbajain). But its production would not stop after 15 years. Regardless of investment or production efficiency, geothermal power generation should be assigned some priority in Tibet.

Tibet started a new attempt to produce geothermal power in 2008. The China Longyuan Power Group Ltd. tested a 1 MWe unit of a screw expander which has been produced by the Jiangxi Huadian Electric Power Co. Ltd. The initial plan was to use thermal waste water of 80°C from the Yangbajain Geothermal Power Plant, however this was not successful. Later, the discharge of deep well ZK4001 was used. It was started in October 2009 and was successful. In

2010 another 1MWe screw expander unit was added to the first pilot plant. Now the 2×1 MWe units are running well.

In 2011, the Jiangxi Huadian Electric Power Co. Ltd. tried to develop the Yangyi Geothermal Field. A 400 kWe screw expander unit was installed using existing Well ZK200 and ran well. Then the Dangxiong County Yangyi Geothermal Power Station Co. Ltd. was founded in the same year. It will undertake the development of the Yangyi Geothermal Field and have gained support from the Tibet Autonomous Region Government, the Tibet Development and Reform Committee, and the Tibet Bureau of Electric Power.

The Tibet Autonomous Region Government organized a special geothermal conference on 22 September 2011 in Tibet. Both Vice Presidents of the Tibet Autonomous Region Government attended the conference. The conference discussed the Tibet Geothermal Development Programming, the construction of the Yangyi Geothermal Power Plant, and matters concerning at the "Tibet Geothermal Development Engineering Research Center". The Government also organized the "Ceremony for Laying the Foundation of the Yangyi Geothermal Power Plant and the Connection of the Pilot Unit to the Grid" on 23 September. As the principle partners, both the Jiangxi Huadian and the Tibet Huadian companies intensify their steps. One partner looks after geothermal exploration and production well drilling. A geophysical CSAMT survey has been carried out during autumn and winter of 2011. It interpreted geological structures down to 3 km depth (previous drilling depth in about 1,000m). Based on the result, sites for new geothermal production wells have been laid out and drilling started in July 2012. The other partner prepares the power plant construction. The Southwest Electric Power Design Institute has completed the feasibility study for the first stage of power plant construction. In order to increase the reliability, the installed capacity of 20 MWe has been reduced to 16 MWe. This feasibility study has passed an expert review in June of 2012. According to the schedule, the first stage engineering will be completed to start power generation at the end of 2013.

Except for production engineering, the Tibet Geothermal Development Engineering Research Center is being established. It is considered to rely on the Yangyi Geothermal Power Plant, to organize concerned leaders, famous geothermal experts and professors to participate in some group research. It is expected to become the technical core for geothermal programming, research and engineering implementation in Tibet. Geothermal power generation has stagnated nearly 30 years in China. We have to intensify efforts to catch up and need to accelerate our research and development activities.

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